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| **Recommendation ITU-R P.2145-0**  **(08/2022)** |
| **Digital maps related to the calculation of gaseous attenuation and related effects** |
| **P Series**  **Radiowave propagation** |

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Resolution ITU‑R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU‑T/ITU‑R/ISO/IEC and the ITU-R patent information database can also be found.

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| Series of ITU-R Recommendations  (Also available online at <http://www.itu.int/publ/R-REC/en>) | |
| **Series** | Title |
| **BO** | Satellite delivery |
| **BR** | Recording for production, archival and play-out; film for television |
| **BS** | Broadcasting service (sound) |
| **BT** | Broadcasting service (television) |
| **F** | Fixed service |
| **M** | Mobile, radiodetermination, amateur and related satellite services |
| P | Radiowave propagation |
| **RA** | Radio astronomy |
| **RS** | Remote sensing systems |
| **S** | Fixed-satellite service |
| **SA** | Space applications and meteorology |
| **SF** | Frequency sharing and coordination between fixed-satellite and fixed service systems |
| **SM** | Spectrum management |
| **SNG** | Satellite news gathering |
| **TF** | Time signals and frequency standards emissions |
| **V** | Vocabulary and related subjects |

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| ***Note***: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.* |

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RECOMMENDATION ITU-R P.2145-0

Digital maps related to the calculation of gaseous attenuation and related effects

(Question ITU-R [201-7/3](https://www.itu.int/pub/R-QUE-SG03.201))

(2022)

Scope

This Recommendation provides methods to predict the surface total (barometric) pressure, surface temperature, surface water vapour density and integrated water vapour content[[1]](#footnote-1) required for the calculation of gaseous attenuation and related effects on terrestrial and Earth-space paths.

Keywords

Surface total (barometric) pressure, surface temperature, surface water vapour density, integrated water vapour content, Weibull probability distribution, Weibull shape, Weibull scale, Earth-space paths

Acronyms/Abbreviations

ASCII American Standard Code for Information Interchange

CCDF Complementary cumulative distribution function

ECMWF European Centre for Medium-Range Weather Forecasts

Related ITU-R Recommendations and Handbook

Recommendation ITU-R [P.528](https://www.itu.int/rec/R-REC-P.528/en)

Recommendation ITU-R [P.530](https://www.itu.int/rec/R-REC-P.530/en)

Recommendation ITU-R [P.618](https://www.itu.int/rec/R-REC-P.618/en)

Recommendation ITU-R [P.619](https://www.itu.int/rec/R-REC-P.619/en)

Recommendation ITU-R [P.676](https://www.itu.int/rec/R-REC-P.676/en)

Recommendation ITU-R [P.836](https://www.itu.int/rec/R-REC-P.836/en)

Recommendation ITU-R [P.1144](https://www.itu.int/rec/R-REC-P.1144/en)

Recommendation ITU-R [P.1510](https://www.itu.int/rec/R-REC-P.1510/en)

Recommendation ITU-R [P.1511](https://www.itu.int/rec/R-REC-P.1511/en)

Recommendation ITU-R [P.1853](https://www.itu.int/rec/R-REC-P.1853/en)

Recommendation ITU-R [P.2001](https://www.itu.int/rec/R-REC-P.2001/en)

Recommendation ITU-R [P.2041](https://www.itu.int/rec/R-REC-P.2041/en)

[Handbook on Radiometeorology](https://www.itu.int/pub/R-HDB-26)

NOTE – The latest revision/edition of the Recommendation/Handbook should be used.

The ITU Radiocommunication Assembly,

considering

*a)* that for the calculation of gaseous attenuation and related effects, surface total (barometric) pressure, surface temperature, surface water vapour density, and integrated water vapour content statistics are needed;

*b)* that 30 years of worldwide fifth generation reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF) are available for surface total (barometric) pressure, surface temperature, surface water vapour density, and integrated water vapour content; and

*c)* that 30 years of worldwide reanalysis data have been post-processed to provide annual and monthly statistics of surface total (barometric) pressure, surface temperature, surface water vapour density and integrated water vapour content,

recommends

that the information in the Annex should be used for the calculation of gaseous attenuation and related effects on terrestrial and Earth-space paths, when more accurate local surface total (barometric) pressure, surface temperature, surface water vapour density, or integrated water vapour content statistics are not available.

Annex

List of symbols

|  |  |
| --- | --- |
|  | mean total (barometric) surface pressure |
|  | standard deviation of surface pressure |
|  | surface total (barometric) pressure vs. exceedance probability |
|  | mean surface temperature |
|  | standard deviation of surface temperature |
|  | surface temperature vs. exceedance probability |
|  | mean surface water vapour density |
|  | standard deviation of surface water vapour density |
|  | surface water vapour density vs. exceedance probability |
|  | mean integrated water vapour content |
|  | standard deviation of integrated water vapour content |
|  | integrated water vapour content vs. exceedance probability |
|  | pressure scale height |
|  | temperature scale height |
|  | water vapour scale height |
|  | surface height above mean sea level |
|  | Weibull shape parameter of integrated water vapour content |
|  | Weibull scale parameter of integrated water vapour content |
|  | exceedance probability (CCDF) |
|  | exceedance probability above the desired exceedance probability |
|  | exceedance probability below the desired exceedance probability |
|  | unscaled value of the parameter of interest at the grid point |
|  | value of the parameter of interest at the grid point at the desired height |
|  | value of the parameter of interest at the desired location at the desired height |

# 1 Annual and monthly meteorological statistical parameters

Digital maps of the worldwide annual and monthly statistics of surface total (barometric) pressure, , in hPa, surface temperature, , in K, and surface water vapour density, , in g/m3, are an integral part of this Recommendation with the characteristics shown in Tables 1, 2 and 3[[2]](#footnote-2).

Digital maps of the worldwide annual and monthly statistics of integrated water vapour content, , in kg/m2, or, equivalently, mm, are an integral part of this Recommendation with the characteristics shown in Tables 1 and 4.

Digital maps of the worldwide annual statistics of integrated water vapour content, , approximated by a Weibull distribution are an integral part of this Recommendation with the characteristics shown in Tables 1 and 5.

Specifically:

– map files with “P” in the title contain values of mean surface total (barometric) pressure, , standard deviation of surface total (barometric) pressure, , and surface total (barometric) pressure vs. exceedance probability, ;

– map files with “T” in the title contain the values of mean surface temperature, , standard deviation of surface temperature, , and surface temperature vs. exceedance probability, ;

– map files with “RHO” in the title contain the values of mean surface water vapour density, , standard deviation of surface water vapour density, , and surface water vapour density vs. exceedance probability, ;

– map files with “V” in the title contain the values of mean integrated water vapour content, , standard deviation of integrated water vapour content, , and integrated water vapour content vs. exceedance probability, (p);

– map files with “PSCH” in the title contain the values of surface total (barometric) pressure scale height, ;

– map files with “TSCH” in the title contain the values of surface temperature scale height, ;

– map files with “VSCH” in the title contain the values of surface water vapour density and integrated water vapour content scale height, ;

– the map file Z\_ground.TXT contains the values of the surface height above mean sea level, ;

– the map file with “kV” in the title contains the values of the shape parameter, , of the Weibull probability distribution of integrated water vapour content; and

– the map file with “lambdaV” in the title contains the values of the scale parameter, , of the Weibull probability distribution of integrated water vapour content.

TABLE 1

Map file characteristics

|  |  |
| --- | --- |
| Parameter | Value |
| Format | ASCII |
| Upper left corner latitude | −90° N |
| Latitude increment | +0.25° |
| Upper left corner longitude | −180° E |
| Longitude increment | +0.25° |
| Number of rows | 721 |
| Number of columns | 1 441 |
| Column separator | Space |
| Row separator | Windows (CR LF) |

TABLE 2

Annual surface total (barometric) pressure, surface temperature and surface water vapour density maps

| Parameters | | Annual pressure (hPa) | Annual temperature (K) | Annual water vapour density (g/m3) |
| --- | --- | --- | --- | --- |
| Mean | | P\_mean.TXT | T\_mean.TXT | RHO\_mean.TXT |
| Standard deviation | | P\_std.TXT | T\_std.TXT | RHO\_std.TXT |
| Exceedance probability (CCDF)[[3]](#footnote-3) | 0.01% | P\_001.TXT | T\_001.TXT | RHO\_001.TXT |
| 0.02% | P\_002.TXT | T\_002.TXT | RHO\_002.TXT |
| 0.03% | P\_003.TXT | T\_003.TXT | RHO\_003.TXT |
| 0.05% | P\_005.TXT | T\_005.TXT | RHO\_005.TXT |
| 0.1% | P\_01.TXT | T\_01.TXT | RHO\_01.TXT |
| 0.2% | P\_02.TXT | T\_02.TXT | RHO\_02.TXT |
| 0.3% | P\_03.TXT | T\_03.TXT | RHO\_03.TXT |
| 0.5% | P\_05.TXT | T\_05.TXT | RHO\_05.TXT |
| 1% | P\_1.TXT | T\_1.TXT | RHO\_1.TXT |
| 2% | P\_2.TXT | T\_2.TXT | RHO\_2.TXT |
| 3% | P\_3.TXT | T\_3.TXT | RHO\_3.TXT |
| 5% | P\_5.TXT | T\_5.TXT | RHO\_5.TXT |
| 10% | P\_10.TXT | T\_10.TXT | RHO\_10.TXT |
| 20% | P\_20.TXT | T\_20.TXT | RHO\_20.TXT |
| 30% | P\_30.TXT | T\_30.TXT | RHO\_30.TXT |
| 50% | P\_50.TXT | T\_50.TXT | RHO\_50.TXT |
| 60% | P\_60.TXT | T\_60.TXT | RHO\_60.TXT |
| 70% | P\_70.TXT | T\_70.TXT | RHO\_70.TXT |
| 80% | P\_80.TXT | T\_80.TXT | RHO\_80.TXT |
| 90% | P\_90.TXT | T\_90.TXT | RHO\_90.TXT |
| 95% | P\_95.TXT | T\_95.TXT | RHO\_95.TXT |
| 99% | P\_99.TXT | T\_99.TXT | RHO\_99.TXT |
| Scale height | | PSCH.TXT | TSCH.TXT | VSCH.TXT |
| Surface height | | Z\_ground.TXT | | |
| File name | | P\_Annual.zip | T\_Annual.zip | RHO\_Annual.zip |
| Integral product file name | | Annual: [Part 1](https://www.itu.int/rec/R-REC-P.2145Part01-0-202208-I/en) | | |

TABLE 3

Monthly surface total (barometric) pressure, surface temperature, and surface water vapour density maps (XX: Jan = 01; Feb = 02; …; Nov = 11; Dec = 12)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | | Monthly pressure (hPa) | Monthly temperature (K) | Monthly water vapour density (g/m3) |
| Mean | | P\_mean.TXT | T\_mean.TXT | RHO\_mean.TXT |
| Standard deviation | | P\_std.TXT | T\_std..TXT | RHO\_std.TXT |
| Exceedance probability (CCDF) | 0.1% | P\_01.TXT | T\_01.TXT | RHO\_01.TXT |
| 0.2% | P\_02.TXT | T\_02.TXT | RHO\_02.TXT |
| 0.3% | P\_03.TXT | T\_03.TXT | RHO\_03.TXT |
| 0.5% | P\_05.TXT | T\_05.TXT | RHO\_05.TXT |
| 1% | P\_1.TXT | T\_1.TXT | RHO\_1.TXT |
| 2% | P\_2.TXT | T\_2.TXT | RHO\_2.TXT |
| 3% | P\_3.TXT | T\_3.TXT | RHO\_3.TXT |
| 5% | P\_5.TXT | T\_5.TXT | RHO\_5.TXT |
| 10% | P\_10.TXT | T\_10.TXT | RHO\_10.TXT |
| 20% | P\_20.TXT | T\_20.TXT | RHO\_20.TXT |
| 30% | P\_30.TXT | T\_30.TXT | RHO\_30.TXT |
| 50% | P\_50.TXT | T\_50.TXT | RHO\_50.TXT |
| 60% | P\_60.TXT | T\_60.TXT | RHO\_60.TXT |
| 70% | P\_70.TXT | T\_70.TXT | RHO\_70.TXT |
| 80% | P\_80.TXT | T\_80.TXT | RHO\_80.TXT |
| 90% | P\_90.TXT | T\_90.TXT | RHO\_90.TXT |
| 95% | P\_95.TXT | T\_95.TXT | RHO\_95.TXT |
| 99% | P\_99.TXT | T\_99.TXT | RHO\_99.TXT |
| Scale height | | PSCH.TXT | TSCH.TXT | VSCH.TXT |
| Surface height | | Z\_ground.TXT | | |
| File name | | P\_MonthXX.zip | T\_MonthXX.zip | RHO\_MonthXX.zip |
| Integral product file name | | Month01: [Part 2](https://www.itu.int/rec/R-REC-P.2145Part02-0-202208-I/en)  Month02: [Part 3](https://www.itu.int/rec/R-REC-P.2145Part03-0-202208-I/en)  Month03: [Part 4](https://www.itu.int/rec/R-REC-P.2145Part04-0-202208-I/en)  Month04: [Part 5](https://www.itu.int/rec/R-REC-P.2145Part05-0-202208-I/en)  Month05: [Part 6](https://www.itu.int/rec/R-REC-P.2145Part06-0-202208-I/en)  Month06: [Part 7](https://www.itu.int/rec/R-REC-P.2145Part07-0-202208-I/en)  Month07: [Part 8](https://www.itu.int/rec/R-REC-P.2145Part08-0-202208-I/en)  Month08: [Part 9](https://www.itu.int/rec/R-REC-P.2145Part09-0-202208-I/en)  Month09: [Part 10](https://www.itu.int/rec/R-REC-P.2145Part10-0-202208-I/en)  Month10: [Part 11](https://www.itu.int/rec/R-REC-P.2145Part11-0-202208-I/en)  Month11: [Part 12](https://www.itu.int/rec/R-REC-P.2145Part12-0-202208-I/en)  Month12: [Part 13](https://www.itu.int/rec/R-REC-P.2145Part13-0-202208-I/en) | | |

TABLE 4

Annual and monthly integrated water vapour content maps  
(XX: Jan = 01; Feb = 02; …; Nov = 11; Dec = 12)

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Annual integrated water vapour content (kg/m2 or mm) | Monthly integrated water vapour content (kg/m2 or mm) |
| Mean | | V\_mean.TXT | V\_mean.TXT |
| Standard deviation | | V\_std.TXT | V\_std.TXT |
| Exceedance probability (CCDF) | 0.01% | V\_001.TXT | - |
| 0.02% | V\_002.TXT | - |
| 0.03% | V\_003.TXT | - |
| 0.05% | V\_005.TXT | - |
| 0.1% | V\_01.TXT | V\_01.TXT |
| 0.2% | V\_02.TXT | V\_02.TXT |
| 0.3% | V\_03.TXT | V\_03.TXT |
| 0.5% | V\_05.TXT | V\_05.TXT |
| 1% | V\_1.TXT | V\_1.TXT |
| 2% | V\_2.TXT | V\_2.TXT |
| 3% | V\_3.TXT | V\_3.TXT |
| 5% | V\_5.TXT | V\_5.TXT |
| 10% | V\_10.TXT | V\_10.TXT |
| 20% | V\_20.TXT | V\_20.TXT |
| 30% | V\_30.TXT | V\_30.TXT |
| 50% | V\_50.TXT | V\_50.TXT |
| 60% | V\_60.TXT | V\_60.TXT |
| 70% | V\_70.TXT | V\_70.TXT |
| 80% | V\_80.TXT | V\_80.TXT |
| 90% | V\_90.TXT | V\_90.TXT |
| 95% | V\_95.TXT | V\_95.TXT |
| 99% | V\_99.TXT | V\_99.TXT |
| Scale height | | VSCH.TXT | VSCH.TXT |
| Surface height | | Z\_ground.TXT | |
| File name | | V\_Annual.zip | V\_MonthXX.zip |
| Integral product file name | | Annual: [Part 1](https://www.itu.int/rec/R-REC-P.2145Part01-0-202208-I/en) | Month01: [Part 2](https://www.itu.int/rec/R-REC-P.2145Part02-0-202208-I/en)  Month02: [Part 3](https://www.itu.int/rec/R-REC-P.2145Part03-0-202208-I/en)  Month03: [Part 4](https://www.itu.int/rec/R-REC-P.2145Part04-0-202208-I/en)  Month04: [Part 5](https://www.itu.int/rec/R-REC-P.2145Part05-0-202208-I/en)  Month05: [Part 6](https://www.itu.int/rec/R-REC-P.2145Part06-0-202208-I/en)  Month06: [Part 7](https://www.itu.int/rec/R-REC-P.2145Part07-0-202208-I/en)  Month07: [Part 8](https://www.itu.int/rec/R-REC-P.2145Part08-0-202208-I/en)  Month08: [Part 9](https://www.itu.int/rec/R-REC-P.2145Part09-0-202208-I/en)  Month09: [Part 10](https://www.itu.int/rec/R-REC-P.2145Part10-0-202208-I/en)  Month10: [Part 11](https://www.itu.int/rec/R-REC-P.2145Part11-0-202208-I/en)  Month11: [Part 12](https://www.itu.int/rec/R-REC-P.2145Part12-0-202208-I/en)  Month12: [Part 13](https://www.itu.int/rec/R-REC-P.2145Part13-0-202208-I/en) |

TABLE 5

Annual statistics of integrated water vapour content  
approximated by a Weibull distribution

|  |  |
| --- | --- |
| Parameter | Annual Weibull approximation |
| Weibull scale | lambdaV.TXT |
| Weibull shape | kV.TXT |
| Scale height | VSCH.TXT |
| Surface height | Z\_ground.TXT |
| File name | Weibull\_Annual.zip |
| Integral product file name | [Part 14](https://www.itu.int/rec/R-REC-P.2145Part14-0-202208-I/en) |

# 2 Interpolation

Section 2.1 provides the statistical and spatial interpolation method to calculate the annual and monthly pressure, temperature, water vapour density, and integrated water vapour content vs. exceedance probability (CCDF) at any desired location on the surface of the Earth.

Section 2.2 provides a statistical and spatial interpolation method to calculate the annual and monthly mean and standard deviation of pressure, temperature, water vapour density, integrated water vapour content, and Weibull integrated water vapour content shape and scale parameters at any desired location on the surface of the Earth.

**2.1 Spatial and statistical (CCDF) interpolation**

The annual or monthly surface total (barometric) pressure statistics, , surface temperature statistics, surface water vapour density statistics, , or integrated water vapour content statistics, , at any desired location on the surface of the Earth and exceedance probability (CCDF), , within the exceedance probability range of the integral digital maps can be calculated using the following interpolation method:

a) determine the height above mean sea level of the desired location, , from local data, or, if local data is not available, from Recommendation ITU-R [P.1511](https://www.itu.int/rec/R-REC-P.1511/en);

b) determine the two exceedance probabilities, *pabove* and *pbelow*, above and below the desired exceedance probability, *p*, from the set: 0.01, 0.02, 0.03, 0.05, 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99% for annual statistics and from the set: 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99% for monthly statistics;

c) for each of the four surrounding grid points, = 1, 2, 3 and 4, and for the two exceedance probabilities, *pabove* and *pbelow*, determine the desired parameter of interest, , from the appropriate annual or monthly map of , , or (p);

d) for each of the four surrounding grid points, = 1, 2, 3 and 4, determine the applicable scale height, , or , from the appropriate annual or monthly pressure, temperature, or water vapour scale height map;

e) for each of the four surrounding grid points, = 1, 2, 3 and 4, determine the topographic height, , as the value of at each grid point from the Z\_ground map;

f) for each of the four surrounding grid points, = 1, 2, 3 and 4, and for the two exceedance probabilities, *pabove* and *pbelow*, determine , at the desired height, *alt*, by scaling , using the applicable relation:

|  |  |  |
| --- | --- | --- |
|  |  | for surface total (barometric) pressure, |
|  |  | for surface temperature, |
|  |  | for surface water vapour density, or |
|  |  | for integrated water vapour content, (p); |

g) determine *Xabove* and *Xbelow* at the desired location and the two probabilities *pabove* and *pbelow* by performing a bilinear interpolation of , *i* = 1, 2, 3 and 4 at the four surrounding grid points using the bilinear interpolation method specified in Annex 1 of Recommendation ITU‑R [P.1144](https://www.itu.int/rec/R-REC-P.1144/en);

h) determine the parameter of interest, *X*, at the desired location and exceedance probability, *p*, by interpolating *Xabove* and *Xbelow* vs. *pabove* and *pbelow* to *p* on a linear *X* vs. log10 *p* scale, where = , , , or .

## 2.2 Spatial and statistical (mean and standard deviation) interpolation

The monthly or annual mean or standard deviation of surface total (barometric) pressure, or , mean or standard deviation of surface temperature, or , mean or standard deviation of surface water vapour density, or , mean or standard deviation of integrated water vapour content, or , or Weibull integrated water vapour content shape or scale parameter, or , at any desired location on the surface of the Earth can be calculated using the following interpolation method:

a) determine the height above mean sea level of the desired location, , from local data, or, if local data is not available, from Recommendation ITU-R [P.1511](https://www.itu.int/rec/R-REC-P.1511/en);

b) for each of the four surrounding grid points, = 1, 2, 3 and 4, determine the desired parameter of interest, , from the appropriate annual or monthly map;

c) for each of the four surrounding grid points, = 1, 2, 3 and 4, determine the applicable scale height, , or , from the appropriate annual or monthly pressure, temperature, or water vapour scale height map;

d) for each of the four surrounding grid points, = 1, 2, 3 and 4, determine the topographic height, , as the value of at each grid point from the Z ground map;

e) for each of the four surrounding grid points, = 1, 2, 3 and 4, determine , at the desired height, *alt*, by scaling , using the applicable relation:

|  |  |  |
| --- | --- | --- |
|  |  | for surface total (barometric) pressure, or |
|  |  | for surface temperature, |
|  |  | for surface temperature, |
|  |  | for surface water vapour density, or |
|  |  | for integrated water vapour content, or ; |
|  |  | for the scale parameter, , of the Weibull probability distribution of integrated water vapour content; or |
|  |  | for the shape parameter, , of the Weibull probability distribution of integrated water vapour content; |

f) determine the parameter of interest, *X*, at the desired location by performing a bilinear interpolation of , *i* = 1, 2, 3, and 4 at the four surrounding grid points using the bilinear interpolation method specified in Annex 1 of Recommendation ITU-R [P.1144](https://www.itu.int/rec/R-REC-P.1144/en), where  =  or , or , or or , , or at the desired location.

1. Integrated water vapour content is the total amount of water vapour in a vertical column extending from the surface of the Earth to the top of the atmosphere. The terms integrated water vapour content, total water vapour content, total column(ar) water vapour, integrated columnar water vapour content, and total columnar content of water vapour are synonymous. [↑](#footnote-ref-1)
2. Surface temperature is defined as the temperature of the air at 2 m above the surface of the Earth. Surface water vapour density is calculated from: a) dewpoint temperature, which is defined as the temperature that the air, at 2 m above the surface of the Earth, would have to be cooled for saturation to occur, b) total surface pressure, and c) surface temperature. [↑](#footnote-ref-2)
3. The terms exceedance probability and complementary cumulative distribution function (CCDF) are synonymous. [↑](#footnote-ref-3)